NASA/TM-2000-209891, Vol. 163



Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Andrea Papagno, Editors

Volume 163 BOREAS TE-10 Photosynthetic Response Data

E. Middleton and J. Sullivan

National Aeronautics and Space Administration

Goddard Space Flight Center Greenbelt, Maryland 20771

The NASA STI Program Office ... in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION.
 English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov/STI-homepage.html
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
 NASA Access Help Desk
 NASA Center for AeroSpace Information
 7121 Standard Drive

Hanover, MD 21076-1320

NASA/TM-2000-209891, Vol. 163



Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Andrea Papagno, Editors

Volume 163 BOREAS TE-10 Photosynthetic Response Data

Elizabeth Middleton, NASA Goddard Space Flight Center, Greenbelt, Maryland Joseph Sullivan, University of Maryland, College Park

National Aeronautics and Space Administration

Goddard Space Flight Center Greenbelt, Maryland 20771

	Available from:	
NIACA Contourfour Armong units of		Notional Tasks: -1 Informed C
NASA Center for AeroSpace Information		National Technical Information Service
7121 Standard Drive		5285 Port Royal Road
Hanover, MD 21076-1320		Springfield, VA 22161
Drica Codo: A17		Dring Code, A10
Price Code: A17		Price Code: A10

BOREAS TE-10 Photosynthetic Response Data

Elizabeth M. Middleton, Joe H. Sullivan

Summary

The BOREAS TE-10 team collected several data sets in support of its efforts to characterize and interpret information on the gas exchange, reflectance, transmittance, chlorophyll content, carbon content, hydrogen content, nitrogen content, and photosynthetic response of boreal vegetation. This data set contains measurements of quantitative parameters and leaf photosynthetic response to increases in light conducted in the SSA during the growing seasons of 1994 and 1996 using an oxygen electrode system. Leaf photosynthetic responses were not collected in 1996. The data are stored in tabular ASCII files.

Table of Contents

- 1) Data Set Overview
- 2) Investigator(s)
- 3) Theory of Measurements
- 4) Equipment
- 5) Data Acquisition Methods
- 6) Observations
- 7) Data Description
- 8) Data Organization
- 9) Data Manipulations
- 10) Errors
- 11) Notes
- 12) Application of the Data Set
- 13) Future Modifications and Plans
- 14) Software
- 15) Data Access
- 16) Output Products and Availability
- 17) References
- 18) Glossary of Terms
- 19) List of Acronyms
- 20) Document Information

1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-10 Photo Response Data

1.2 Data Set Introduction

This data set describes the relationship between sample location, sample age, oxygen evolution measurements, and quantitative parameters in the canopies of the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) Old Black Spruce (OBS), Old Jack Pine (OJP), Young Jack Pine (YJP), Old Aspen (OA), Old Aspen-Auxiliary (OA-AUX), Young Aspen (YA), and Young Aspen-Auxiliary (YA-AUX) sites during the growing seasons of 1994 and 1996. This data set was collected and prepared to provide information on the oxygen evolution measurements and quantitative parameters of OBS (Picea mariana), OJP (Pinus banksiana and Apocynum androsaemifolium), YJP (Pinus banksiana), YA (Populus tremuloides and Corylus cornuta Marsh) OA (Populus tremuloides and Corylus cornuta Marsh, and Picea

glauca), and OA-AUX (Populus tremuloides and Corylus cornuta Marsh). This information will be useful for assessing photosynthetic differences between different species, age classes, and canopy layers in the boreal forest.

1.3 Objective/Purpose

The purposes of the work were to:

- Obtain a canopy profile of leaf/needle growth measurements and oxygen evolution rates during photosynthesis.
- Examine interspecific and interseasonal differences in these parameters.
- Relate these differences to the photosynthetic measurements taken in the field.

1.4 Summary of Parameters

The photo response data record includes the date when the measurements were taken, quantitative parameters (color of top of leaf, color of bottom of leaf, needle count per sample, mean leaf/needle length of three needles per age class or three measurements of the same leaf, mean leaf/needle width of three needles per age class or three measurements of the same leaf, mean leaf/needle thickness of three needles per age class or three measurements of the same leaf, length/width ratio, mean hemisurface area of three needles per age class or three measurements of the same leaf, dry and fresh weights of leaf/petiole/needle, dry and fresh weights of leaf/petiole/needle/stem, fresh specific leaf weight, dry specific leaf weight, percent water content for the whole shoot including stem, percent water in the sample without stem), and oxygen evolution (maximum assimilation-Amax, dark respiration-darkresp, and stomatal limitation-stomlim).

1.5 Discussion

Samples were taken from seven forest sites in the SSA: OBS, OJP, YJP, YA-AUX, YA, OA-AUX, and OA during each of the three Intensive Field Campaigns (IFCs) in 1994 and the growing season of 1996. Measurements were taken in the laboratory. Quantitative measurements such as length, width, thickness, color, needle count/age class, and fresh weight were examined in an effort to characterize photosynthetic differences. An oxygen electrode system (Hansatech Corporation, Kingslynn, England), which measures the rate of oxygen evolution during photosynthesis, was used for photosynthesis measurements under controlled light and temperature and with saturating concentrations of carbon dioxide (CO₂) (5, 10% in air), which overcome stomatal resistances to CO₂ uptake. This information will be useful in examining differences in photosynthetic capacity between species and within canopies of the boreal forest. Measurements were taken in the laboratory.

1.6 Related Data Sets

BOREAS TE-10 Leaf Chlorophyll BOREAS TE-10 Leaf Optical Properties

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Elizabeth Middleton Project Scientist Dr. Joseph Sullivan Assistant Professor

2.2 Title of Investigation

CO₂ and Water Fluxes in the Boreal Forest Overstory: Relationship to fAPAR and Vegetation Indices for Needles/Leaves

2.3 Contact Information

Contact 1:

Elizabeth M. Middleton, Ph.D. Biospheric Sciences Branch, Code 923 NASA GSFC Greenbelt, MD 20771 (301) 286-8344 (301) 286-0239 (fax) betsym@ltpsun.gsfc.nasa.gov

Contact 2:

Joe H. Sullivan, Ph.D.
Department of Natural Resource Sciences and Landscape Architecture University of Maryland
College Park, MD 20742
(301) 405-1626
(301) 314-9308 (fax)
botn9@umdd.umd.edu

Contact 3:

Andrea Papagno Raytheon ITSS Code 923 NASA GSFC Greenbelt, MD 20771 (301) 286-3134 (301) 286-2039 (fax) Andrea.Papagno.gsfc.nasa.gov

Contact 4:

Shelaine Curd Raytheon ITSS Code 923 NASA GSFC Greenbelt, MD 20771 (301) 286-2447 (301) 286-2039 (fax) Shelaine.Curd@gsfc.nasa.gov

3. Theory of Measurements

An oxygen electrode system (Hansatech Corporation, Kingslynn, England), which measures the rate of oxygen evolution during photosynthesis, was used for photosynthesis measurements under controlled light and temperature and with saturating concentrations of CO_2 (5, 10% in air), which overcome stomatal resistances to CO_2 uptake. Single-leaf measurements were made using cut leaf disks having areas of 2.27 cm² of aspen, hazelnut, and dogbane. For full illumination by the light source, enough material was needed to fill the electrode system chamber without any overlap; thus, multiple needle samples were used to measure the coniferous species. Five needles within the same sample id and the same age class were used to measure jack pine; 15 to 20 needles within the sample id and the same needle age class were used to measure black spruce. Saturating photosynthetic photon flux density (PPFD) (2175 μ mol/m²/s) was supplied by a Bjorkman lamp connected to a Hansatech

LS-2 light source. Estimates of dark respiration (darkresp) were made after incremental light reductions (implemented for light response curves, Middleton et al. [1997] and Sullivan et al. [1996]) and acclimation to zero illumination.

Stomatal limitation is calculated using the standard equation from Farquhar and Sharkey (1982):

stomatal limitation =
$$((a_{max} - A)/a_{max}) \times 100$$
 (1)

Terrestrial Ecology (TE)-10 used maximum assimilation without stomatal limitations (a_{max}) from the light-saturated and CO_2 -saturated O_2 measurements as an estimate of " a_{max} ," and light-saturated maximum assimilation with stomatal limitations (A) from field measurements using an Infrared Gas Analyzer (IRGA) System. Amax from O_2 is without a stomatal effect because of the high CO_2 gradient overcoming any stomatal barrier to diffusion. A in the field does potentially include some other limitations in addition to stomatal closure (e.g., biochemical), but that possibility was ignored. This is an accepted way to estimate how much influence the stomates are having on gas exchange.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

The vertical profile of the canopy was divided into three layers: top, middle, and bottom. One layer of white spruce at YA-AUX was measured during IFC-2 only. At OJP, the understory species dogbane (Apocynum androsaemifolium) was measured during IFC-2. At OA and YA, there was a hazelnut (Corylus cornuta Marsh) understory that was measured during each IFC.

Gas exchange measurements and sample collections were made from platform canopy access towers constructed onsite by the BOREAS staff at the OBS, OJP, OA, and OA-AUX sites and from the ground at the YA, YA-AUX, and YJP sites. In 1994, data were obtained during three discrete measurement periods (1 to 2 measurement days each period) designated by BOREAS as IFC-1, -2, or -3. These IFCs were selected to measure parameters at bud breaks and leaf expansion (24-May-1994 to 12-Jun-1994), midsummer or peak growing season (26-Jul-1994 to 08-Aug-1994), and the onset of dormancy and senescence in autumn (30-Aug-1994 to 15-Sep-1994). In 1996, data were obtained during three discrete measurement periods (1 to 2 measurement days each period) designated as the spring, summer, and fall seasons. These seasons were selected to measure parameters at bud breaks and leaf expansion (21-April-1996 to 24-June-1996), midsummer or peak growing season (10-July-1996 to 17-July-1996), and the onset of dormancy and senescence in autumn (20-Oct-1996 to 31-Oct-1996).

Measurements were collected from both the upper and lower canopy sections of the trees adjacent to the canopy access towers at the OJP, OBS, OA, and OA-AUX sites and on the young trees present near the flux tower sites at the YJP, YA, and YA-AUX sites. For Pinus banksiana, measurements were made on each needle class present. For Picea glauca, age classes 1 (1994) and 2 (1993) were measured during IFCs-2 and -3. For Picea mariana, the newest age was measured alone, while needles 2 and 3 years were combined in one measurement, as were 4- and 5-year-old needles. Broadleafs were measured as individual leaves with their petioles attached. At least eight replicate measurements and sample collection per IFC, canopy location, and age group were made for each species. These activities took place on trees that were accessible from the canopy access towers (approximately four trees, with two upper and lower branches measured per tree) at the OBS, OJP, OA, and OA-AUX sites and on the same number of trees each IFC at the YJP, YA, and YA-AUX sites.

Samples were sealed in plastic bags with moist towels and placed on ice for transport to the laboratory for further analysis. The laboratory was provided by BOREAS staff in Paddockwood, SK, approximately 60 km from the research sites. Each sample was divided into two components with one portion used for measurement of oxygen evolution and chlorophyll extraction and the remaining material used for analysis of leaf optical properties and carbon-hydrogen-nitrogen content.

At the laboratory, samples were stored in the dark in the refrigerator until they were measured. Laboratory measurements included quantitative properties, optical properties, and oxygen evolution. Quantitative parameters included the color of top of the leaf, the color of the bottom of the leaf, needle count per sample, mean leaf/needle length of three needles per age class or three measurements of the same leaf, mean leaf/needle width of three needles per age class or three measurements of the same leaf, mean leaf/needle thickness of three needles per age class or three measurements of the same leaf, dry and fresh weights of leaf/petiole/needle, and dry and fresh weights of leaf/petiole/needle/stem. A foliar disk sample of 2.27 cm² diameter was taken from each of the broadleaf samples for oxygen evolution. A mass of needles, 5 for jack pine and 15 to 20 for black spruce, chopped, was taken from the conifers for oxygen evolution. The foliar disk samples and chopped needles were dried and weighed following the extraction of their photosynthetic pigments. The rest of the samples were dried in an oven at 70 °F for 3 days, and their dry weights were recorded. The oxygen evolution samples were of a known weight.

4.1.2 Source/Platform

Samples were taken from towers except at YJP, YA-AUX, and YA, and were cut using knives.

4.1.3 Source/Platform Mission Objectives

Not applicable.

4.1.4 Key Variables

Oxygen evolution (maximum assimilation-Amax, dark respiration-darkresp, stomatal limitation-stomlim).

Quantitative parameters (color of top of leaf, color of bottom of leaf, needle count per sample, mean leaf/needle length of three needles per age class or three measurements of the same leaf, mean leaf/needle width of three needles per age class or three measurements of the same leaf, mean leaf/needle thickness of three needles per age class or three measurements of the same leaf, length/width ratio, mean hemisurface area of three needles per age class or three measurements of the same leaf, dry and fresh weights of leaf/petiole/needle, dry and fresh weights of leaf/petiole/needle/stem, fresh specific leaf weight, dry specific leaf weight, percent water content for the whole shoot including stem, and percent water in the sample without stem).

4.1.5 Principles of Operation

Maximum assimilation and dark respiration were obtained from the rates of oxygen evolution. An oxygen electrode system (Hansatech Corporation, Kingslynn, England), which measures the rate of oxygen evolution during photosynthesis, was used for photosynthesis measurements under controlled light and temperature and with saturating concentrations of CO₂ (5, 10% in air), which overcome stomatal resistances to CO₂ uptake. Single-leaf measurements were made using cut leaf disks having areas of 2.27 cm² of aspen, hazelnut, and dogbane. For full illumination by the light sources enough material was needed to fill the electrode system chamber without any overlap; thus, multiple needle samples were used to measure the coniferous species. Five needles within the same sample id and the same age class were used to measure jack pine; 15 to 20 needles within the sample id and the same needle age class were used to measure black spruce. Stomatal limitation was calculated using the standard equation from Farquhar and Sharkey (1982). Quantitative measurements enabled TE-10 to measure the percent water content and to obtain leaf/needle dimensions.

4.1.6 Sensor/Instrument Geometry

All instrumentation took place under laboratory conditions.

4.1.7 Manufacturer of Sensor/Instrument

Circulating Water Bath Set Lauda, Model RM20B Fisher Scientific 585 Alpha Drive Pittsburgh, PA 15238 1 (800) 766-7000

LED Light Source Hansatech Model LH36 Ultralight Hansatech Corporation Kingslynn, UK

LI-COR Area Meter Model Number 3100 LI-COR, Inc. 4421 Superior Street P.O. Box 4425 Lincoln, NE 68504-0425 USA (402) 467-3576 (402) 467-2819 (fax)

Oxygen Electrode Hansatech Corporation Kingslynn, UK

4.2 Calibration

4.2.1 Specifications

The weighing balance was accurate to 0.01 g. The analytical balance was accurate to 0.0001 g. The leaf area meter was accurate to within 1.00%.

4.2.1.1 Tolerance

No tolerance level was set.

4.2.2 Frequency of Calibration

The oxygen evolution system was calibrated using O_2 (1 cc air) injected into the system before each sample run. The leaf area meter was calibrated before each use with a 10-cm disk. Measurements of weight (mass) were reset to zero before each sample reading.

4.2.3 Other Calibration Information

None.

5. Data Acquisition Methods

On the towers at OA, OA-AUX, OBS, YJP, and OJP, top samples were taken from the top tower level, middle samples from the middle level, and bottom samples from the bottom tower level. At YA and YA-AUX, top samples were taken from the upper third, middle samples from the middle third, and bottom samples from the lower third part of the trees. At YA-AUX, only a top layer of the white spruce (Picea glauca) canopy was sampled. At OJP, there was a dogbane (Apocynum androsaemifolium) understory during IFC-2. At OA and YA, there was a hazelnut (Corylus cornuta Marsh) understory. Stem and leaf samples were harvested from each layer and immediately placed

within a plastic bag that also contained a moist towel. For transport to the laboratory, the bags were placed in a cooler. For black spruce, age classes 1, 2, and 3 were separated from ages 4 and 5, until analysis was performed at the laboratory. For jack pine, age classes 1, 2, and 3 were separated in the field before being brought to the laboratory. For white spruce, age class 1 was separated from age classes 2 and 3, which were separated from 4 and 5. Petioles were kept on all the broadleaves. At the laboratory, samples were stored in the dark in the refrigerator until they were measured.

Laboratory measurements included quantitative properties, optical properties, and oxygen evolution. Quantitative measurements that were performed on each sample age class included fresh weight using a balance; mean leaf (hemi-surface) area using a leaf area meter; mean length, mean width, and mean thickness of leaf/needles and conifer stems using a ruler and calipers; color of top (adaxial) and bottom (abaxial) using Munsell Color Charts (Munsell Color (Firm), 1977); and needle count/age class. An oxygen electrode system (Hansatech Corporation, Kingslynn, England), which measures the rate of oxygen evolution during photosynthesis, was used for photosynthesis measurements under controlled light and temperature and with saturating concentrations of CO₂ (5, 10% in air), which overcome stomatal resistances to CO₂ uptake. Measurements were made on leaf discs or needle subsets. Single-leaf measurements were made using cut leaf disks having areas of 2.27 cm² of aspen, hazelnut, and dogbane. For full illumination by the light source, enough material was needed to fill the electrode system chamber without any overlap; thus, multiple needle samples were used to measure the coniferous species. Five needles within the same sample id and the same age class were used to measure jack pine; 15 to 20 needles within the sample id and the same needle age class were used to measure black spruce. The electrode was maintained at a constant temperature using a circulating water bath (Lauda, Model RM20B), reset to approximately maximum daytime air temperature per IFC (26 °C in IFC-1 and -3, 28 °C in IFC-2). Photosynthesis capacity (light-saturated photosynthesis) or Amax was determined within 2 to 24 hours after the field measurements. Saturating PPFD (2175 µmol/m²/s) was supplied by a Bjorkman lamp connected to a Hansatech LS-2 light source. Estimates of dark respiration (darkresp) were made after incremental light reductions (implemented for light response curves, Middleton et al. [1997] and Sullivan et al. [1996]) and acclimation to zero illumination.

6. Observations

6.1 Data NotesNone.

6.2 Field Notes None.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

At the SSA OJP, YJP, OBS, OA, and OA-AUX tower sites, branch samples were taken from trees within reach from all sides of the towers. There were no towers at the other sites. At each site, at least five trees had the required layers for that site were sampled. The SSA measurement sites and associated North American Datum of 1983 (NAD83) coordinates are:

 SSA-OA canopy access tower located 100 m up the path to the flux tower site, site id C3B7T, Lat/Long: 53.62889° N, 106.19779° W, Universal Transverse Mercator (UTM) Zone 13, N:5,942,899.9 E:420,790.5.

- SSA-OA-AUX canopy access tower located by the trailhead/parking area for the path leading to the flux tower at site id C3B7T, Lat/Long: 53.62889° N, 106.19779° W, UTM Zone 13, N:5,942,899.9 E:420,790.5. This OA-AUX site was farther up the path than SSA-OA from the flux tower site.
- SSA-OBS canopy access tower located at the flux tower site, site id G8I4T, Lat/Long: 53.98717° N, 105.11779° W, UTM Zone 13, N:5,982,100.5 E;492,276.5.
- SSA-OJP canopy access tower flux tower site, site id G2L3T, Lat/Long: 53.91634° N, 104.69203° W, UTM Zone 13, N:5,974,257.5 E:520,227.7.
- SSA-YA canopy access tower, site id D0H4T, Lat/Long: 53.65601° N, 105.32314° W, UTM Zone 13, N:5,945,298.9, E:478,644.1.
- SSA-YA-AUX, site id D6H4A, Lat/Long: 53.708° N, 105.315° W, UTM Zone 13, N:5,951,112.1, E:479,177.5.
- SSA-YJP near the flux tower site, site id F8L6T, Lat/Long: 53.87581° N, 104.64529° W, UTM Zone 13, N:5,969,762.5 E:523,320.2.

7.1.2 Spatial Coverage Map

Not applicable.

7.1.3 Spatial Resolution

These data are point measurements at the given locations.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

Samples were collected from the field every day from 0900 until 1300 local time. An independent data set was taken at each of the field campaigns in 1994. The specific dates for each collection of samples are given in the data table.

7.2.2 Temporal Coverage Map

	Sample Dates (1994)			
Site	Species	IFC-1	IFC-2	IFC-3
SSA-OBS	black spruce	01-JUN	28-JUL to 01-AUG	13-SEP
SSA-OA-AUX	aspen	-	03-AUG	02-SEP
SSA-OA-AUX	hazelnut	_	03-AUG	02-SEP
SSA-OJP	jack pine	31-MAY	25-JUL	06-SEP
SSA-OJP	dogbane	_	25-JUL	_
SSA-OA	aspen	30-MAY,11-JUN	21-JUL	15-SEP
SSA-OA	hazelnut	26-MAY,11-JUN	21-JUL	15-SEP
SSA-YA-AUX	aspen	25-MAY	-	_
SSA-YJP	jack pine	26-MAY,07-JUN	22-JUL to 23-JUL	08-SEP
SSA-YA-AUX	white spruce	_	31-JUL to 01-AUG	11-SEP
SSA-YA	aspen	04-JUN	30-JUL	02-SEP,12-SEP
SSA-YA	hazelnut	04-JUN	30-JUL	02-SEP,12-SEP

Sample Dates (19	Sample	Dates	(1996)
------------------	--------	-------	--------

Site	Species	Spring	Summer	Fall
SSA-OBS	black spruce	10-MAY	14-JUL	11-OCT
SSA-OBS	black spruce	19-JUN	-	-
SSA-OBS	black spruce	21-JUN	-	-
SSA-OBS	tamarack	-	17-JUL	10-OCT
SSA-OJP	jack pine	18-JUN	11-JUL	13-OCT
SSA-OJP	jack pine	23-JUN	-	-
SSA-OA-AUX	aspen	24-JUN	17-JUL	-
SSA-OA-AUX	hazelnut	24-JUN	17-JUL	-
SSA-YJP	jack pine	8-MAY TO 9-MAY	12-JUL	12-OCT
SSA-YJP	jack pine	23-JUN	15-JUL	-
SSA-YA-AUX	white spruce	8-MAY	10-JUL	10-OCT
SSA-YA-AUX	white spruce	20-JUN	-	-

7.2.3 Temporal Resolution Not applicable.

7.3 Data Characteristics

7.3.1 Parameter/VariableThe parameters contained in the data files on the CD-ROM are:

Column Name
SITE_NAME SUB_SITE DATE_OBS SPECIES CANOPY_LOCATION SAMPLE_GROWTH_YEAR
SAMPLE_ID MEAN_FOLIAGE_HEMI_SURF_AREA_GY
ADAXIAL_MUNSELL_COLOR ABAXIAL_MUNSELL_COLOR
NUM_TOTAL_NEEDLES MEAN_LEAF_LENGTH MEAN LEAF WIDTH
MEAN_LEAF_WIDIH LEAF_LENGTH_TO_WIDTH_RATIO MEAN_LEAF_THICKNESS
DARK_RESPIRATION STOMATAL_LIMITATION
MAXIMUM_ASSIMILATION TOTAL_FRESH_WEIGHT
FRESH_LEAF_WEIGHT FRESH_LEAF_DENSITY TOTAL DRY WEIGHT
DRY_LEAF_WEIGHT DRY_WEIGHT_RATIO
DRY_LEAF_DENSITY SHOOT_WATER_CONTENT LEAF_WATER_CONTENT CRTFCN_CODE
REVISION_DATE

7.3.2 Variable Description/DefinitionThe descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
SPECIES	Botanical (Latin) name of the species (Genus
	species).
CANOPY_LOCATION	Location in the canopy from which the sample was taken.
SAMPLE_GROWTH_YEAR	The year in which the collected sample first
	grew.
SAMPLE_ID	The sample identifier used by data collectors
MEAN_FOLIAGE_HEMI_SURF_AREA_GY	The hemi-surface foliar area of the broadleaf plus its petiole or of all the needles in the needle growth year.
ADAXIAL_MUNSELL_COLOR	Munsell color code of the adaxial surface.
ABAXIAL_MUNSELL_COLOR	Munsell color code of the abaxial surface.
NUM_TOTAL_NEEDLES	The total number of needles on the shoot.
MEAN_LEAF_LENGTH	The mean lengths of three conifer needles within the same growth year or of three measurements of the same foliar broadleaf (the petiole is not included).
MEAN_LEAF_WIDTH	The mean widths of three conifer needles within
	the same growth year or of three measurements of the same foliar broadleaf (the petiole is not included) .
LEAF_LENGTH_TO_WIDTH_RATIO	The ratio of the mean leaf length to the mean leaf width.
MEAN_LEAF_THICKNESS	The mean thicknesses of three conifer needles within the same growth year or of three measurements of the same foliar broadleaf (the
DARK_RESPIRATION	petiole is not included). The lowest assimilation rate reached (negative) by a foliar broadleaf or needle sample under zero light illumination.
STOMATAL_LIMITATION	The limitation of photosynthesis by the stomates. This is calculated using the maximum photosynthesis reached under light saturating conditions with and without stomatal influence.
MAXIMUM_ASSIMILATION	The maximum assimilation reached by a plants

leaves/needles under light saturating conditions

and without stomatal limitations.

TOTAL_FRESH_WEIGHT The total fresh weight of the broadleaf and

petiole or the total of all the needles and

needle stems in the needle growth year.

FRESH_LEAF_WEIGHT The fresh weight of a single broadleaf and

petiole or all of the needles (minus the needle

stem) in the needle growth year.

FRESH_LEAF_DENSITY The fresh leaf weight of the broadleaf and its

petiole or all the needles in the needle growth year per their mean growth year foliar area.

TOTAL_DRY_WEIGHT The total dry weight of the broadleaf and petiole

or the total of all the needles and needle stems

in the needle growth year.

DRY_LEAF_WEIGHT The dry weight of a single broadleaf and petiole

or all of the needles in the needle growth year. The ratio of dry leaf weight to the total dry

weight values.

DRY_LEAF_DENSITY The dry leaf weight of the broadleaf and its

petiole or all the needles in the needle growth year per their mean growth year foliar area. The percentage of water in the whole conifer

shoot or of the broadleaf and petiole. This is calculated as the total fresh weight minus the total dry weight divided by the total fresh

weight.

LEAF WATER CONTENT

The percentage of water in the single broadleaf

and petiole or in all of the needles in the needle growth year. This is calculated as the fresh leaf weight minus the dry leaf weight

divided by the fresh leaf weight.

CRTFCN CODE The BOREAS certification level of the data.

Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI

but questionable).

REVISION_DATE The most recent date when the information in the

referenced data base table record was revised.

Units

7.3.3 Unit of Measurement

Column Name

DRY WEIGHT RATIO

SHOOT WATER CONTENT

The measurement units for the parameters contained in the data files on the CD-ROM are:

SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
SPECIES	[none]
CANOPY_LOCATION	[none]
SAMPLE_GROWTH_YEAR	[unitless]
SAMPLE_ID	[none]

MEAN_FOLIAGE_HEMI_SURF_AREA_GY [millimeters^2]

ADAXIAL_MUNSELL_COLOR [none]
ABAXIAL_MUNSELL_COLOR [none]
NUM_TOTAL_NEEDLES [counts]

MEAN_LEAF_LENGTH [millimeters] MEAN_LEAF_WIDTH [millimeters] LEAF LENGTH TO WIDTH RATIO [unitless] MEAN_LEAF_THICKNESS [millimeters] DARK RESPIRATION [micromoles 02][meter^-2][second^-1] STOMATAL_LIMITATION [percent] [micromoles O2][meter^-2][second^-1] MAXIMUM ASSIMILATION TOTAL_FRESH_WEIGHT [grams] FRESH LEAF WEIGHT [grams] FRESH_LEAF_DENSITY [grams][millimeter^-2] TOTAL_DRY_WEIGHT [grams] DRY_LEAF_WEIGHT [grams] DRY_WEIGHT_RATIO [unitless] DRY LEAF DENSITY [grams][millimeter^-2] SHOOT_WATER_CONTENT [percent] LEAF_WATER_CONTENT [percent] CRTFCN_CODE [none] [DD-MON-YY] REVISION DATE

7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SITE NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_OBS	[Human Observer]
SPECIES	[Human Observer]
CANOPY_LOCATION	[Human Observer]
SAMPLE_GROWTH_YEAR	[Human Observer]
SAMPLE_ID	[Human Observer]
MEAN_FOLIAGE_HEMI_SURF_AREA_GY	[Laboratory Equipment]
ADAXIAL_MUNSELL_COLOR	[Human Observer]
ABAXIAL_MUNSELL_COLOR	[Human Observer]
NUM_TOTAL_NEEDLES	[Human Observer]
MEAN_LEAF_LENGTH	[Laboratory Equipment]
MEAN_LEAF_WIDTH	[Laboratory Equipment]
LEAF_LENGTH_TO_WIDTH_RATIO	[Laboratory Equipment]
MEAN_LEAF_THICKNESS	[Laboratory Equipment]
DARK_RESPIRATION	[Laboratory Equipment]
STOMATAL_LIMITATION	[Laboratory Equipment]
MAXIMUM_ASSIMILATION	[Laboratory Equipment]
TOTAL_FRESH_WEIGHT	[Laboratory Equipment]
FRESH_LEAF_WEIGHT	[Laboratory Equipment]
FRESH_LEAF_DENSITY	[Laboratory Equipment]
TOTAL_DRY_WEIGHT	[Laboratory Equipment]
DRY_LEAF_WEIGHT	[Laboratory Equipment]
DRY_WEIGHT_RATIO	[Laboratory Equipment]
DRY_LEAF_DENSITY	[Laboratory Equipment]
SHOOT_WATER_CONTENT	[Laboratory Equipment]
LEAF_WATER_CONTENT	[Laboratory Equipment]
CRTFCN_CODE	[BORIS Designation]
REVISION_DATE	[BORIS Designation]

7.3.5 Data RangeThe following table gives information about the parameter values found in the data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-90A-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE10-LPR01	9TE10-LPR02	None	None	None	None
DATE_OBS	25-MAY-94	13-OCT-96	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
CANOPY_LOCATION	Bottom	Top	-999	None	None	None
SAMPLE_GROWTH_YEAR	1989	1996	-999	None	None	None
SAMPLE_ID	N/A	N/A	-999	None	None	None
MEAN_FOLIAGE_HEMI_	113	10828	-999	None	None	Blank
SURF_AREA_GY						
ADAXIAL_MUNSELL_	.5gy4/8	7.5gy7/10	-999	None	None	Blank
COLOR						
ABAXIAL_MUNSELL_	2.5gy4/4	7.5gy8/6	-999	None	None	Blank
COLOR						
NUM_TOTAL_NEEDLES	1	219	-999	None	None	Blank
MEAN_LEAF_LENGTH	4.34	161	-999	None	None	Blank
MEAN_LEAF_WIDTH	.664	107.06	-999	None	None	Blank
LEAF_LENGTH_TO_	.694	25.639	-999	None	None	Blank
WIDTH_RATIO						
MEAN_LEAF_THICKNESS	.13	1.93	-999	None	None	Blank
DARK_RESPIRATION	-10.81	2.4	-999	None	None	Blank
STOMATAL_LIMITATION	1.372	268.919	-999	None	None	Blank
MAXIMUM_ASSIMILATION		57.7	-999	None	None	Blank
TOTAL_FRESH_WEIGHT	.04	6.93	-999	None	None	Blank
FRESH_LEAF_WEIGHT	0	6.25	-999	None	None	Blank
FRESH_LEAF_DENSITY	0	10.97525	-999	None	None	Blank
TOTAL_DRY_WEIGHT	.005	2.95	-999	None	None	Blank
DRY_LEAF_WEIGHT	.005	1.908	-999	None	None	Blank
DRY_WEIGHT_RATIO	.231	1.024	-999	None	None	Blank
DRY_LEAF_DENSITY	.00001	5.36861	-999	None	None	Blank
SHOOT_WATER_CONTENT	-20	100	-999	None	None	Blank
LEAF_WATER_CONTENT	0	100	-999	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	10-SEP-98	10-SEP-98	None	None	None	None

Minimum Data Value -- The minimum value found in the column.

Maximum Data Value -- The maximum value found in the column.

Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.

Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be unreliable by the analysis personnel.

Below Detect Limit -- The value that indicates parameter values below the instruments detection limits. This is used to indicate that an attempt was made to determine the parameter value, but the analysis personnel determined

that the parameter value was below the detection limit of the instrumentation.

Data Not Cllctd

-- This value indicates that no attempt was made to determine the parameter value. This usually indicates that BORIS combined several similar but not identical data sets into the same data base table but this particular science team did not measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value. N/A -- Indicates that the value is not applicable to the respective column. None -- Indicates that no values of that sort were found in the column.

7.4 Sample Data Record

The following are wrapped versions of data record from a sample data file on the CD-ROM.

SITE_NAME, SUB_SITE, DATE_OBS, SPECIES, CANOPY_LOCATION, SAMPLE_GROWTH_YEAR, SAMPLE_ID, MEAN_FOLIAGE_HEMI_SURF_AREA_GY, ADAXIAL_MUNSELL_COLOR, ABAXIAL_MUNSELL_COLOR, NUM_TOTAL_NEEDLES, MEAN_LEAF_LENGTH, MEAN_LEAF_WIDTH, LEAF_LENGTH_TO_WIDTH_RATIO, MEAN_LEAF_THICKNESS, DARK_RESPIRATION, STOMATAL_LIMITATION, MAXIMUM_ASSIMILATION, TOTAL_FRESH_WEIGHT, FRESH_LEAF_WEIGHT, FRESH_LEAF_DENSITY, TOTAL_DRY_WEIGHT, DRY_LEAF_WEIGHT, DRY_LEAF_DENSITY, SHOOT_WATER_CONTENT, LEAF_WATER_CONTENT, CRTFCN_CODE, REVISION_DATE

'SSA-9OA-FLXTR', '9TE10-LPR01', 26-MAY-94, 'Corylus cornuta', 'Top', '1994', '14', 285.0, '2.5gy6/10', '2.5gy6/8', -999.0, 29.0, 19.0, 1.526, -999.0, -999.0, -999.0, -999.0, .05, .05, 1.75439, .049, .049, -999.0, 1.7193, 2.0, 2.0, 'CPI', 10-SEP-98

'SSA-9OA-FLXTR', '9TE10-LPR01', 26-MAY-94, 'Corylus cornuta', 'Top', '1994', '15', 263.0, '2.5gy6/10', '5gy5/6', -999.0, 24.0, 16.0, 1.5, -999.0, -999.0, -999.0, -999.0, -999.0, .04, .04, 1.52091, .01, .01, -999.0, .38023, 75.0, 75.0, 'CPI', 10-SEP-98

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by the BOREAS Information System (BORIS) was the data collected at a given site on a given date.

8.2 Data Format(s)

The Compact Disk-Read Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of HyperText Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae

stomlim = $[(a_{max}-A)/a_{max}]100$ (Farquhar and Sharkey, 1982)

9.1.1 Derivation Techniques and Algorithms

None.

9.2 Data Processing Sequence

9.2.1 Processing Steps

Oxygen evolution measurements were recorded manually. Subsequent calculations were performed using Quattro Pro 6.0 for Windows 3.1.

9.2.2 Processing Changes

None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None.

9.3.2 Calculated Variables

stomatal limitation = [(amax-A)/amax]100 (Farquhar and Sharkey, 1982)

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

Errors are primarily caused by variation in researchers' measurement techniques and in instrumentation. The data have received a quality review by TE-10 personnel, and all known sources of calculation errors have been corrected.

10.2 Quality Assessment

Data have received a quality review by TE-10 personnel.

10.2.1 Data Validation by Source

Comparisons were made with other BOREAS results and with published results.

10.2.2 Confidence Level/Accuracy Judgment

None available, but it is felt that these data are accurate.

10.2.3 Measurement Error for Parameters

Not available.

10.2.4 Additional Quality Assessments

Calculated results were plotted and the plots were compared with those from published papers.

10.2.5 Data Verification by Data Center

Data were examined for general consistency and clarity.

11. Notes

11.1 Limitations of the Data

None.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

None.

11.4 Other Relevant Information

None.

12. Application of the Data Set

These data can be used for assessing photosynthetic differences between different species, age classes, and canopy layers in the boreal forest.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

Calculations were performed using Quattro Pro 6.0 for Windows 3.1. This document was prepared using Microsoft Word 5.1a for the Macintosh.

14.2 Software Access

None given.

15. Data Access

The photo response data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services Oak Ridge National Laboratory P.O. Box 2008 MS-6407 Oak Ridge, TN 3781-6407

Phone: (423) 241-3952 Fax: (423) 574-4665

E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products

None.

16.3 Other Products

These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

LI-3100 LI-COR Area Meter Manual. Publication number 8805-0055, June 1988. LI-COR, Inc., 4421 Superior Street, P.O. Box 4425, Lincoln, NÈ 68504-0425.

17.2 Journal Article and Study Reports

Farquhar, G.D. and T.D. Sharkey. 1982. Stomatal conductance and photosynthesis. Annu. Rev. Plant Physiol. v33: 317-345.

Kharouk, V.I., E.M. Middleton, S.L. Spensor, B.N. Rock, and D.L. Williams. 1995. Aspen bark photosynthesis and its significance to remote sensing and carbon budget estimates in the boreal ecosystem. Water, Air and Soil Pollution. V82: 483-497.

Middleton, E.M., E.W. Chappelle, and A. DeLuca. 1995. Evaluating photosynthesis in boreal forest species with fluorescence measurements. IGARSS 1995.

Middleton, E.M., J.H. Sullivan, B.D. Bovard, A.J. DeLuca, S.S. Chan, and T.A. Cannon. 1997. Seasonal variability in foliar characteristics and physiology for boreal forest species at the five Saskatchewan tower sites during the 1994 Boreal Ecosystem-Atmosphere Study. Journal of Geophysical Research 102(D24):28,831-28,844.

Munsell Color (Firm). 1977. Munsell Color Charts for Plants Tissues. 2nd ed. Munsell Color (Firm), Baltimore, MD, 6 pp. 17 color charts.

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

Sullivan, J.H., B.D. Bovard, and E.M. Middleton. 1996. Variability in leaf-level CO₂ and water fluxes in Pinus banksiana and Picea mariana in Saskatchewan. Tree Physiol. V17: 553-561.

17.3 Archive/DBMS Usage Documentation None.

18. Glossary of Terms

A - The maximum assimilation reached by a plant's leaves/needles under light-saturating conditions and having stomatal limitations. This was measured in the field using an IRGA system.

 A_{max} - The maximum assimilation reached by a plant's leaves/needles under light-saturating conditions and without stomatal limitations. This was measured in the laboratory using an oxygen electrode system.

Darkresp - The dark respiration by a plant's leaves/needles is the lowest assimilation rate reached (negative) under zero light illumination.

Stomatal limitation - The percent by which the stomates limit photosynthesis by a plant.

19. List of Acronyms

ASCII - American Standard Code for Information Interchange

BARC - Beltsville Agricultural Research Center

BOREAS - BOReal Ecosystem-Atmosphere Study

BORIS - BOREAS Information System CD-ROM - Compact Disk-Read-Only Memory DAAC - Distributed Active Archive Center

db - Dogbane

- Earth Observing System EOS

EOSDIS - EOS Data and Information System GIS - Geographic Information SystemGSFC - Goddard Space Flight Center

haz - Hazelnut

HTML - HyperText Markup Language - Intensive Field Campaign IFC IRGA - Infrared Gas Analyzer

NAD83 - North American Datum of 1983

NASA - National Aeronautics and Space Administration

NSA - Northern Study Area

- Old Aspen OA

OA-AUX - Old Aspen-Auxiliary OBS - Old Aspen-Auxiliary
OBS - Old Black Spruce
OJP - Old Jack Pine
ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park
PPFD - Photosynthetic Photon Flux Density
SSA - Southern Study Area

- Terrestrial Ecology URL - Uniform Resource Locator

USDA - United States Department of Agusta - Universal Transverse Mercator - United States Department of Agriculture

WS - White Spruce YA - Young Aspen

YA-AUX - Young Aspen-Auxiliary

YJP - Young Jack Pine

20. Document Information

20.1 Revision Date

Written: 21-Aug-1997 Last Updated: 13-Aug-1999

20.2 Document Review Date(s)

BORIS Review: 14-Aug-1998

Science Review:

20.3 Document ID

20.4 Citation

When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:

Middleton, E.M., of the Biospheric Sciences Branch, GSFC, NASA, and Sullivan, J.H., of the Department of Department of Natural Resource Sciences and Landscape Architecture, University of Maryland, College Park.

If using data from the BOREAS CD-ROM series, also reference the data as:

Middleton, E. and J. Sullivan, "CO₂ and Water Fluxes in the Boreal Forest Overstory: Relationship to fAPAR and Vegetation Indices for Needles/Leaves." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

20.5 Document Curator

20.6 Document URL

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE October 2000	3. REPORT TYPE AND DATES COVERED Technical Memorandum	
4. TITLE AND SUBTITLE Technical Report Series on the Bo BOREAS TE-10 Photosynthe	•	e Study (BOREAS)	5. FUNDING NUMBERS 923
6. AUTHOR(S) Elizabeth Middleton and Jose Forrest G. Hall and Andrea Pa		RTOP: 923-462-33-01	
7. PERFORMING ORGANIZATION NAME Goddard Space Flight Center Greenbelt, Maryland 20771	E(S) AND ADDRESS (ES)		8. PEFORMING ORGANIZATION REPORT NUMBER 2000-03136-0
9. SPONSORING / MONITORING AGE National Aeronautics and Space Washington, DC 20546-0001		5 (ES)	10. SPONSORING / MONITORING AGENCY REPORT NUMBER TM—2000–209891 Vol. 163
11. SUPPLEMENTARY NOTES J. Sullivan: University of Man A. Papagno: Raytheon ITSS,	NASA Goddard Space F	light Center, Gree	nbelt, Maryland
12a. DISTRIBUTION / AVAILABILITY STA Unclassified—Unlimited Subject Category: 43 Report available from the NASA 7121 Standard Drive, Hanover,	A Center for AeroSpace Inf	·	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The BOREAS TE-10 team collected several data sets in support of its efforts to characterize and interpret information on the gas exchange, reflectance, transmittance, chlorophyll content, carbon content, hydrogen content, nitrogen content, and photosynthetic response of boreal vegetation. This data set contains measurements of quantitative parameters and leaf photosynthetic response to increases in light conducted in the SSA during the growing seasons of 1994 and 1996 using an oxygen electrode system. Leaf photosynthetic responses were not collected in 1996. The data are stored in tabular ASCII files.

BOREAS, terrestrial ecology, boreal vegetation.			15. NUMBER OF PAGES 20 16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT $UL \\$